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Probing order beyond the Landau paradigm

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For many years, it was thought that Landau's theory of symmetry breaking could describe essentially all phases and phase transitions. Then, in 1982, the limitations of Landau theory were exposed in a dramatic way with the discovery of the fractional quantum Hall (FQH) effect. The FQH states contain a new kind of order - known as "topological order" - that is fundamentally beyond the Landau paradigm. Topological order cannot be understood using symmetry breaking, order parameters, or long range order. This poses an interesting theoretical problem: these states must contain some kind of structure that is responsible for their unusual physical properties. But what is this structure and how can we probe it without order parameters? In my talk, I will describe recent progress in answering this question. I will show that topological order is intimately connected with nonlocal quantum entanglement. I will introduce a new quantity - called "topological entropy" - that measures precisely this nonlocal entanglement.